ECONOMICS OF ENERGY TRANSPORTATION - PETROLEUM AND PETROLEUM PRODUCTS TRANSMISSION

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INTRODUCTION

The transportation of petroleum and petroleum products is at the same time competitive and complementary...trucks compete with railroads and pipelines; pipelines compete with barges and tankers; tankers compete with barges, and so on. At the same time these competitors complement each other in that a single unit of petroleum energy, to achieve its most economical delivery, may be handled by as many as four separate transportation media from the wellhead to the consumers tank.

This complex transportation system supplies some 1-1/2 million tons (approximately 10.9 million barrels per day) of petroleum products daily to such diverse destinations as service stations, home heating tanks, public utilities, railroad fueling yards, ships' bunker tanks, and the nation's airports.

Oil today efficiently supplies 44 percent, per Table 1, of the nation's energy requirements. Some 50 percent of this is supplied to the so-called safe market--motive fuels. Here, severe competition between supplying companies within the oil industry provides every incentive for continuous improvement of transportation facilities. To supply and retain the other 50 percent of oil's energy market, the industry's competition is not only between the many supplying companies, but there is rigorous competition from other energy sources, mainly gas and coal.

Thus, there is not only great emphasis in our business on the economics of transportation, but there is the sheer necessity of competing in the market place if individual companies are to survive and prosper.

I. STATE OF DEVELOPMENT

This transportation of energy is in two parts: the collection at refineries of the crude oil from remote sources and the dispersion of products to the market. While unit transportation costs are low, they are significant and total approximately 2 cents per gallon at such destinations as New York, Chicago, and Los Angeles. Thus, the money to be saved by economical transportation is great, and the justification for investment in freight-saving facilities is correspondingly great.

The main facilities which effect this efficient transportation job form an impressive total as detailed in Table 2. Today's replacement cost minus depreciation is estimated at $7-1/2 billion; original gross investment is perhaps $5 to $6 billion.

In addition to the facilities included in the foregoing, petroleum utilizes such specialized distribution systems as pipeline fueling at seven major commercial airports and about fifty-two military air bases, dozens of marine terminals, pipelines for delivery to utilities and railroad yards, and pipelines for supplying heating oil direct to some 50,000 homes, mainly in housing developments.

Comparative use of petroleum's main transportation facilities and trends in such usage are listed in Table 3. Compared to 1940 and 1950, trucks and pipelines are handling a much larger share of petroleum tonnage delivered daily, but since 1955 the division of tonnage delivered has changed very little. Actually, a precise comparison of the work done by the different categories of transportation should include the distance hauled, with the tabulation expressed in ton-miles, but statistics on this basis are not available. It is evident, however, that since the pipeline and marine categories transport petroleum the longest distances, they thus perform the bulk of the ton-mile transportation job.

What are the economic forces which have led to this "state of development"? Basic, of course, is the competitive drive already noted, but the trends and improvements in new facilities reflect the economic impact of two major factors: (A) large-lot transport over maximum distance, (B) technological development including automation.

A. LARGE-LOT CONCEPT

Super tankers, large barge tows, jumbo tank cars, mammoth trucks, large diameter pipelines all testify to the simple economic fact that large quantities can be transported cheaper than small quantities--per ton. Costs are spread over more units. Extra handling is also minimized by the large trucks delivering direct from refineries and terminals to service stations and consumers, thus bypassing bulk depots. Table 4 illustrates the size of today's transportation equipment and how it compares with that of twenty years ago.

Amount of freight saved by the large-lot concept is illustrated in Table 5. Thus, for example, a new 47-M DWT tanker saves, roughly, 50 percent versus a new 16-M DWT T-2 type tanker (which is no longer economic to build) on the Gulf-New York run; a 24-inch diameter line saves about

60 percent versus a 10-inch line; a jumbo 20,000-gallon tank car can save 25 percent on a 1,000-mile haul versus a 10,000-gallon car; and an 8,500-gallon truck saves 15-30 percent on a 50-mile haul (100-mile round trip) versus a 6,500-gallon size.

Economic assessment of utilizing large equipment necessarily takes into account other factors than just the point to point freight saved. Specifically, the large-lot concept requires large tankage and inventory at delivering and receiving points. In the case of super tankers, it also requires deep berths, heavy piers, and rapid loading and unloading facilities. Terminal size and investment to service large marine equipment versus small are compared in an example in Table 6. This suggests that certain minimum throughputs must be achieved for the freight saved by the "large-lot" carrier to offset the extra cost of terminal facilities and inventory required for the big ships.

While the economic incentives behind the large-lot concept are, of course, age-old and not peculiar to oil, our industry is now able to exploit to a high degree the economies of the large-lot concept because of several developments: (1) sufficient underlying demands, (2) improvement of rivers and harbors, (3) improved highway system.

1. Sufficient Underlying Demands

Use of pipeline and marine transportation obviously depends on establishment of a minimum demand level, and for a minimum sized products pipeline of some 6-inch diameter and 100 miles long, such demand is roughly 10,000 barrels per day versus trucking. For a barge terminal, it is about 1,000 barrels per day versus trucking. Growth in population has brought combined product demand levels in more and more urban areas (and a 50-mile surrounding area) not only to these minima but also to the minima required to pay out pipelines versus marine transportation--where the latter is handicapped by a longer route or winter ice. Examples of the latter: West Shore Pipe Line (Chicago to Green Bay), Wolverine Pipe Line (Chicago to lake ports), Olympic Pipe Line (Puget Sound to Portland). Growth of demand for single, hard-to-handle products such as propane has also reached the point where volume makes pipeline transportation feasible. Texas Eastern, Mid-America and Dixie Pipe Lines are examples of common carrier pipelines now handling propane. Similarly, LPG tankers and barges have become feasible for coast-wise and inland waterway movement of propane.

2. Improvements of Rivers and Harbors

Extensive harbor improvements for the larger draft ocean tankers are programmed per Table 7. Examples:

	LARGEST TANKER (M DWT)		PROJECT
	NOW	FUTURE	COMPLETION DATE
New York	47	85	1967
San Francisco	38	85	1965

Through extensive work by the Federal Government during the 1930's, many of the inland rivers were opened to reasonable (9-foot) draft barge transportation, and, of course, barge terminals were established in coastal harbors and waterways. Two current barge projects of significance are (a) the lock enlargements on the Ohio River to 1,200 feet each (formerly 600 feet) to accommodate large tows, and (b) the John Day Dam on the Columbia, which will eliminate the present 7-foot draft bottleneck. Table 8 lists the current schedule of lock improvements on the Ohio.

Total Federal appropriations for navigation improvements alone (as distinguished from flood control and other purposes) were $225 million in 1963, rising from a low of $25 million in 1954, per Table 9 attached.

3. Improved Highways

Improved highways have permitted exploitation of the large-lot concept. Economics dictate that a $30,000 truck (some cost $50,000) spends maximum percent of its time in transit and minimum at loading and unloading point. The nation's super highways permit heavy loads, rapid transportation, and more miles per driver shift. 15,000 miles of the Federal interstate highways system were open to traffic in 1963. The over-all program totalling 41,000 miles is scheduled for completion by 1971.

Before passing on from this direct consideration of the large-lot concept, a realistic word concerning service requirements would be in order. Petroleum is a universal fuel, particularly for motive power, and demand levels in many sectors dictate less than jumbo size facilities. Consequently, there is a substantial requirement for providing optimum facilities, whether they be pipeline, truck or marine. Likewise the customers' facilities and policy toward inventory levels must be an important consideration in determining transportation facilities.

B. TECHNOLOGICAL DEVELOPMENTS

The nature of today's transportation facilities dramatically reflects technological advances in construction, maintenance, automation, operation, and auxiliary services. Exploitation of the large-lot delivery concept itself depends on such advances. Improvements range from better materials and more efficient prime movers to corrosion control and automated equipment.

In pipelines, the technological developments are first, faster and more economical pipe installation with such equipment as improved ditch diggers, in-the-field coating machines, in-the-field pipe fabricators, automatic welding, and X-ray inspection devices; second, higher tensile strength steel which has permitted reduction of pipe tonnage by 50 percent since 1948; third, improved product separation techniques through such devices as rubber spheres and motorized valves; fourth, improved metering of large capacities; fifth, development of lease automatic custody transfer equipment; sixth, improved telemetry and so-called push-button controls, permitting operation of entire pipelines from a central console; seventh, corrosion control by cathodic protection and improved coatings, both internal and external. Based on Interstate Commerce Commission statistics, reductions in pipeline personnel from 1952 to 1962 amounted to 50 percent of station labor, 35 percent of maintenance personnel, and 23 percent of gaugers.

In marine equipment the technological development of suitable wharves, hose handling rigs, and offshore moorings has been of perhaps greater importance in exploiting the large-lot concept than the mere (but not to be minimized) technology of building large, fast ships. Examples are the elaborate wharves and hose handling gear at industry wharves in New York Harbor, offshore mooring in 65 feet of water at Northville, Long Island, and crude oil loading facilities in the Louisiana Delta region and under development off the Louisiana shore in 75 feet of water. Improved centrifugal pumps, which also reduce cargo stripping time, have made significant reductions in vessel operating expense in recent years. Improved integrated barge tow configuration has significantly reduced drag and thus increased efficiency. On the Mississippi and Ohio Rivers mid-stream fueling and victualling have shortened in-port time, while radio and radar have speeded transit times. Significant automation developments in marine equipment are in engine room controls and remote handling of cargo. Manning scales on tankers are being reduced on the order of five men; from a range of thirty-five to forty previously to thirty to thirty-five in the future. Such reductions, and those which may be effected later through further mechanization or the transfer to shore staff of present-day shipboard functions (maintenance, cargo handling, etc.), will require the cooperation of the maritime unions. In the case of licensed personnel and watch standers, the approval of the U. S. Coast Guard will also be a requirement. Inland waterway operators have made greater progress in these areas than tanker operators; a typical 8,000-ton tow, for instance, with wheelhouse control of the engine room and in some cases revised galley arrangements, has nine crew men vs. twelve crew men ten years ago.

In tank cars the technological development of 20,000 and 30,000-gallon capacities has been a major breakthrough realized just in the last ten years. There is even a 50,000-gallon car which is utilized in restricted service. In the largest cars the tank itself supports the lading between the trucks, eliminating the center sill. This permits maximum utilization of larger capacity cars while staying within AAR clearance and weight restrictions. In recognition of reduced rail handling expense, the railroads are able to reduce rates by 25 to 40 percent or more for shipments in these cars. (Cf. 1,000-mile example in Table 5.)

In trucks the technology of large capacities has recently reached an all-time high in large-lot deliveries: 16,500 gallons per truck in Michigan. Such a truck has eleven axles. Size and weight are regulated by state law. In 1963, the last state, Pennsylvania, raised its weight limit to the generally accepted standard of 73,280 pounds--equivalent to 8,200 gallons of gasoline. A 6,500-gallon size was considered "large" only ten years ago.

Storage, whether for seasonal accumulation or for working terminal purposes, is a vital part of the transportation network. Technological developments have now provided: (a) relatively cheap seasonal storage for the volatile fuels and (b) much automation at working terminals. As to (a), ordinary steel pressure storage for butane and propane commonly costs $15 to $25 per barrel, but the underground or refrigerated storage developed in recent years costs only $1 to $8 per barrel in large sizes. A substantial amount of the latter, located near the market, is an attractive alternative to extra transportation capacity in the form of more tank cars, larger pipelines, more ships, and so forth, otherwise required to handle peak winter loads. As to (b), at working terminals there has been extensive automation in tank farm gauging devices, automatic custody transfer equipment, blending equipment, and automatic truck loading equipment. This latter has been developed to the point that the truck driver now handles all functions of product loading and metering. Such facilities add $25/50,000 to terminal capital, but rapid payouts are shown where volumes exceed 1,000 barrels per day.

II. COSTS

The economic effect of the large-lot deliveries and technological improvements noted in the preceding paragraphs is incorporated in the freight costs applicable to today's typical (as distinguished from largest) equipment. Considerably larger than twenty years ago, per Table 4, today's typical equipment comprises 25 M DWT tankers, 20 M barrel barges (60 M barrel tows), 10,000 gallon cars, 8,500 gallon trucks, and a wide range of pipeline diameters.

Industry's use of this particular equipment results in freight costs, including reasonable return on investment, which are tabulated according to mileage in Table 10. The wide range in rail and truck rates (often common carrier tariffs) is forced by the diverse competitive conditions which these carriers meet. For a 500-mile haul, the estimated rates are:

	CENTS PER 500 BBL. MILES	AVERAGE ¢/100 BBL. MILE	AVERAGE MILLS/ TON MILE
Pipeline	16-50	5.4	4.0
Tanker	12-15	2.7	2.0
Barge	14-18	3.3	2.5
Tank Car	85-180	27	20
Truck	160-340	46	35

If each of the foregoing transportation facilities is used over a distance for which it is reasonably well suited, the rates may be compared as follows:

	DISTANCE MILES	AVERAGE ¢/100 BBL. MILE	AVERAGE MILLS/ TON MILE
Pipeline	1,000	3.7	2.8
Tanker	2,200	1.6	1.2
Barge	500	3.3	2.5
Tank Car	1,000	23	18
Truck	50	46	35

It is seen from the foregoing that the costs per mile for movement via pipeline and water carriers are normally comparatively close. In practice, the selection of the facilities used must consider, among others, factors such as: the comparative length of the water and pipeline routes, the availability of navigable water, terminalling costs, winter icing problems, and opportunities for intermediate deliveries.

The percentage of costs which vary directly with occupancy has a profound effect on how equipment is utilized and how transportation systems are expanded. In the case of common carrier facilities where the shipper pays marine charter rates and common carrier tariffs, the direct costs coincide generally with the total costs. In the case of privately owned transportation facilities, however, the direct costs are significantly lower, and the cost differential between alternative modes of transportation is changed.

The proportion of fixed and direct costs among the transportation types is about as follows:

	PERCENT	
	FIXED	DIRECT
Pipeline	70-80	20-30
Tanker	20-40	60-80
Barge	30	70
Tank Car	Not applicable because shipper pays rail tariff.	
Private Truck	15-20	80-85

The higher the ratio of fixed to direct costs, the greater the premium on maximum utilization. Thus, tariffs in the case of common carrier pipelines, or shipping territories in the case of privately owned pipelines, are normally established so as to provide optimum utilization of the facility.

The effect of occupancy on transportation costs is recognized in the so-called "Dedicated Service" rates available from for-hire truckers. If, for example, the trucker is assured 120 hours per week utilization of his equipment, the reduction in rates may be 20 to 30 percent; 100 hours per week utilization, the reduction could be 15 to 20 percent; 80 hours per week utilization, the reduction may average 10 percent.

Large-lot delivery and technological improvements are also being utilized to lessen the effect of wage inflation on total transportation expense. The following tabulation shows the approximate percentage of wages in each type of transportation:

	PERCENT OF TOTAL COST WAGES
Pipeline	15
Tanker	30
Barge	35
Tank Car	Not applicable because shipper pays tariff.
Truck	50

Given two types of carrier with roughly the same costs, the oilman is likely to build or buy the one less susceptible to inflationary pressures. This is an important factor in the popularity of pipelines.

III. RESEARCH OPPORTUNITIES

Research work in oil transportation may be classified as both technological and logistical.

In the technological category, research in pipelines is pursuing the following: mechanics of liquid and two-phase flow, corrosion control including internal and external coatings, additives to reduce friction, increased strength of steel pipe, improved plastic pipe, improved welding techniques, mobile pipe mills, underwater pipeline construction, improved communication systems for automation, interface detector systems, mechanical separation of products, improved meters, and computer controlled pipelines.

In the marine field, research is dealing with simplification of design, internal and external coatings for corrosion control, cathodic type corrosion control, improved cargo handling (pumps, valves, gauging), improved offshore moorings, cryogenic transportation, improved propulsion machinery, improved navigation equipment, and automation, including centralized engine room controls.

In tank cars and trucks, the research is in improved materials to minimize weight and optimize strength within the limitations of railroad clearance restrictions, weight limits, and highway regulations; safety devices; faster loading and unloading.

Technological research in terminals continues in the realm of automating terminal controls, accounting and billing functions. In this latter category, equipment is visualized which permits the central office to control the release of products to specific accounts in predetermined amounts, keep terminal inventories, and issue invoices automatically as product is withdrawn.

Logistical research deals with means to optimize shipping territories of supply origins through mathematical techniques. If a particular refinery and its satellite terminals are short of supplies, it is usually less expensive to supplement supplies by shipping into the deficient territory according to certain patterns from refinery systems that have sufficient supplies than to move product by pipeline or marine transportation from one refinery to another. Then too, in a territory where over-all demand just equals supply, but supply is divided in fixed amounts among a number of origins, there is a particular pattern of shipment from origins to destinations which minimizes the total freight bill. This is the classic "transportation problem". While certain companies had developed various techniques to solve this problem "by hand", the method was generally laborious and time-consuming. In the last few years, however, due to research, the solution has been programmed on some of the larger computers and such freight optimization is now in use to a limited, but growing extent. Considerable emphasis now is placed on methods to feed automatically to the computers the statistics comprising account names, demands and freight rates. Logistical research is also progressing on methods to collect, summarize, and project supply and demand data in order to program operation of transportation equipment most efficiently.

IV. ECONOMIC OBJECTIVES

The aims of the oil industry's transportation effort have been and will remain primarily cost reduction, protection of product quality, and improved customer services. From the individual company's viewpoint, however, an even more basic aim has been economic survival. As profit margins in the industry have shrunk through competitive forces, the necessity to utilize advanced transportation facilities and techniques has increased. For example, Oklahoma refiners who originally shipped by tank car and subsequently built the Great Lakes Pipe Line to move products to more distant markets, have, in order to remain competitive, resorted to a number of additional product pipelines: Cherokee, Omar, Kaneb, Continental.

As to trends, the ultimate in efficient energy (petroleum) transportation would include a products line to the customer's oil tank or to the service station. While the connection to the homeowner's heating oil tank is foreseeable only in densely populated housing developments, there is likely to be pipeline delivery of oil to certain high-volume commercial and industrial complexes using oil for all energy needs: heat, refrigeration, electricity. Pipeline connections to service stations have not been installed on any large scale, but such have proved possible at certain high-volume stations which are located close to existing products lines or refineries. The chief development which is being realized and will continue into the future is the proliferation of products lines to serve truck-loading terminals in more and more communities across the country. Direct pipeline connections to industrial users and to airports (commercial and military) will be a by-product of this development.

No dramatic introduction of new type transportation is foreseen; but the already noted pressures of competition and the advantages of large-lot transportation and technological improvement are causing shifts between types of carrier and are revising the physical nature of the industry's transportation system.

Table 1
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PERCENT PETROLEUM IN
TOTAL U.S. ENERGY CONSUMPTION

	PERCENT
Coal	22.2
Oil	44.0*
Gas	29.8
Water Power	3.8
Atomic Power	0.2
TOTAL	100.0

*Includes natural gas liquids.

SOURCE: U.S. Bureau of Mines:
1963 extrapolated to 1965 by
Shell Oil Company

Table 1
Page 2

SOURCES: Shell Oil Company, Transportation and Supplies

Sun Oil Company, Economics Department, Analysis of World Tank Ship Fleet, December 31, 1963.

National Petroleum Council, Oil and Gas Transportation Facilities, 1962.

U. S. Bureau of Mines, U. S. and Puerto Rico Oil Improts, by Quarters for 1963.

American Petroleum Institute, Annual Statistical Bulletin, U. S. Petroleum Industry Statistics 1940-63, 1964.

U. S. Dept. of Commerce, United States Foreign Trade, U. S. Gov't. Printing Office, Feb. 18, 1964.

Corps of Engineers - U. S. Army, Transportation Lines on the Great Lakes System, 1964, Transportation Series 3, U. S. Gov't. Printing Office, 1964.

Corps of Engineers - U. S. Army, Transportation Lines on the Mississippi River System, Transportation Series 4, U. S. Gov't. Printing Office, 1963.

National Petroleum News, Fact Book Mid-May 1964.

U. S. Dept. of Commerce, Merchant Marine Data Sheet, November 1, 1964, U. S. Gov't. Printing Office.

Oil and Gas Journal, October 19, 1964.

Table 2

PETROLEUM TRANSPORTATION FACILITIES

FACILITY	# UNITS	VOLUMETRIC CAPACITY M DWT	VOLUMETRIC CAPACITY MM BBLS.	REPLACEMENT COST LESS DEPRECIATION TO DATE MM $
OCEAN TANKERS				
American Flag	440*	8,912	78.0	
Foreign Flag	233	5,872	51.5	
Supplying U. S.	673	14,784	129.5	1,800
INLAND AND COASTAL BARGES				
Self-Propelled	181		1.7	
Non Self-Propelled	2,494		27.0	
	2,675		28.7	150
PIPELINES - MILES				
Crude Trunk	70,000			
Crude Gathering	78,000			
Products	57,000			
	205,000			3,200
RAIL TANK CARS	131,622		29.5	350
TRUCKS				
Transport	58,448		8.3	
Local Delivery (Gasoline)	22,200		0.6	
(Heating Oils)	70,948		2.7	
	151,596		11.6	1,050
STORAGE AND TERMINALS				
Terminals and Depots	29,664		405.2	
LPG Refrig Storage	8		2.0	
LPG Underground Storage	139		101.9	
	29,811		509.1	1,000
GRAND TOTAL			708.4	7,550**

*As of 11/1/64, 95 ships were inactive, of which 70 were government-owned and 25 private.

**Cf. $5 billion and $6 billion original gross investment as estimated respectively in "Petroleum Transportation Handbook", Harold Sill Bell, Editor, McGraw Hill, 1963, and "The U.S. Petroleum Industry", Stanford Research Institute, 1964.

Table 3

MILLIONS SHORT TONS DELIVERED
TOTAL CRUDE AND PRODUCTS

	PIPELINES		WATER CARRIERS*		TRUCKS		RAIL		TOTAL
	MILLION TONS	% TOTAL	MILLION TONS	% TOTAL	MILLION TONS	% TOTAL	MILLION TONS	% TOTAL	MILLION TONS
1962	502	43.36**	330	28.46	298	25.69	29	2.49	1,159
1961	484	43.60	323	29.06	274	24.64	30	2.70	1,111
1960	469	43.01	318	29.22	270	24.83	32	2.94	1,089
1959	464	43.22	310	28.86	267	24.82	33	3.10	1,074
1958	433	42.57	298	29.36	252	24.78	34	3.29	1,020
1955	412	42.94	284	29.56	223	23.17	42	4.33	961
1950	284	38.82	253	34.57	146	19.93	49	6.68	732
1945	241	44.06	142	26.08	96	17.60	67	12.26	546
1940	154	39.79	149	38.78	22	5.67	61	15.76	386

*U.S. Flag only. If foreign flag deliveries to U.S. ports were added the breakdown would be as follows:

1962	502	40.07	424	33.84	298	23.78	29	2.31	1,253

**The recently constructed 36-inch Colonial products pipeline from the Gulf Coast to New York will increase pipeline and reduce water carrier deliveries by about 2 percent of total deliveries.

SOURCE: The Association of Oil Pipe Lines

Table 4

SIZE OF PETROLEUM TRANSPORTATION FACILITIES

FACILITY	CAPACITY CURRENT NORMAL	CAPACITY CURRENT MAXIMUM	CAPACITY 1945 NORMAL	CAPACITY 1945 MAXIMUM
OCEAN TANKERS (DWT)				
American Flag	25,000*	106,600	15,000	20,600
Foreign Flag Serving U.S.	58,800**	114,800	15,000	16,800
INLAND AND COASTAL BARGE TOWS (Bbls.)				
Inland	60,000	186,000	35,000	60,000
Coastal	20,000	73,000	10,000	25,000
PIPELINES (Diameter in Inches)				
Crude Trunk	10/26"	34"	8/10"	24"***
Crude Gathering	4/10"	12"	4/10"	12"
Products	8/20"	36"	8"	20"***
RAIL TANK CARS (Gallons)	10,000	33,000≠	8,000	12,000
TRUCK-TRAILERS (Gallons)	8,500	16,000	6,000	10,000
TANK TRUCKS (Gallons)				
Gasoline and Heating Oils	2,000	4,400	1,500	3,000

*5 ships totaling 189,000 DWT's were under contruction at end 1963. Only 57 ships of U.S. fleet of 440 ships exceed 30,000 DWT and 144 vessels are greater than 20,000 DWT's. Only 6 ships exceed 50,000 DWT and largest is 106,600 DWT.

**326 ships totaling 18,023,000 DWT's were under construction in Europe plus Japanese yards at end of 1963. Of world fleet of 3,279 ships, 1,365 exceed 20,000 DWT's and 853 exceed 30,000 DWT's. Largest ship (Japanese) is 130,200 DWT and the next two (Liberian) are 114,800 DWT's each.

***Trend toward large diameter pipelines began in 1942 with the War Emergency Big Inch (24") crude and Little Inch (20") products pipelines from the Gulf Coast to the East Coast. Prior to that date the largest oil lines were 12" diameter.

≠At least one 50,000 gallon car in restricted service.

SOURCES:

Shell Oil Company, Transportation and Supplies

Sun Oil Company, Economics Department, Analysis of World Tank Ship Fleet, December 31, 1963.

National Petroleum Council, Oil and Gas Transportation Facilities, 1962.

Corps of Engineers - U.S. Army, Transportation Lines on the Great Lakes System, 1964, Transportation Series 3, U. S. Government Printing Office, 1964.

Corps of Engineers - U.S. Army, Transportation Lines on the Mississippi River System, Transportation Series 4, U. S. Government Printing Office, 1963.

American Petroleum Institute, Petroleum Facts and Figures, 1963 Edition, p. 92 (using Interstate Commerce Commission and Bureau of Mines as sources).

Oil and Gas Journal, various issues and articles.

Table 5

FREIGHT SAVED BY LARGE-LOT CONCEPT

PIPELINE	LINE DIAMETER INCHES	¢/BBL. FOR 1,000 MILES		COST AS PERCENT OF SMALLEST UNIT		PERCENT SAVED VS. SMALLEST UNIT	
	10	51		100		-	
	14	36		71		29	
	18	27		53		47	
	24	21		41		59	
TANKER	SIZE SHIP-DWT	ESTIMATED $/LONG TON GULF-NEW YORK					
	16,000 T-2 (a)	4.20		100		-	
	25,000 (b)	3.02		72		28	
	47,000	1.97		47		53	
	67,000	1.81		43		57	
BARGE	SIZE TOW-BBLS.	¢/BBL. FOR 500 MILES					
	40,000	17.6		100		-	
	60,000	15.7		89		11	
	90,000	14.1		80		20	
TANK CAR	SIZE CAR-GALS.	¢/GAL. FOR 1,000 MILES					
	10,000	5.5		100		-	
	20,000	4.1		75		25	
TRUCK	SIZE TRUCK GALLONS	¢/GAL. FOR 50 MILES PRIVATE	FOR HIRE(c)				
	6,500	0.7	0.7	100	100	-	-
	8,500	0.5	0.6	71	86	29	14

(a) Ships of this size are no longer constructed for this service and are used for comparative purposes only. There are, however, many still in operation on which typical operating costs are closer to $3.20/long ton.

(b) Although $3.02 represents new construction, there are a great number of jumboized T-2's of this capacity which freight for closer to $2.50/long ton.

(c) Based on "Dedicated Service" common carrier.

SOURCE: Shell Oil Company
Transportation and Supplies

Table 6

EXAMPLE OF
EXTRA TERMINAL CAPITAL REQUIRED
TO SERVICE LARGE TANKERS VS. ORDINARY T-2'S;
ALSO MINIMUM THROUGHPUT NECESSARY
TO WARRANT LARGER TERMINAL

	TYPICAL PRODUCTS TERMINAL HANDLING 4 M-B/D				
	SIZED TO HANDLE 16 M DWT T-2 TANKER		SIZED TO HANDLE 37 M DWT TANKER		EXTRA COST OF 37 M DWT TANKER TERMINAL
	SIZE	M-$	SIZE	M-$	M-$
Land and Site Preparation	15 Ac.	165	20 Ac.	220	55
Tankage	260 MB	460	460 MB	805	345
Loading Rack, Office, Misc.	-	250	-	250	-
Dock	525'	1,000	650'	1,500	500
TOTAL		1,875		2,775	900
Inventory @ $3.50/Bbl.		910		1,610	700
GRAND TOTAL		2,785		4,385	1,600

Assume 37 M DWT ship saves 10¢/bbl. vs. older T-2:

Annual cost of 10% representing interest and amortization on $900 M extra cost of terminal	$90 M/Y
Interest alone at 5% on $700 M extra inventory	$35 M/Y
Total extra annual terminal cost	$125 M/Y

Throughput necessary for 15¢/bbl. saving of 37 M DWT Tanker vs. T-2 to offset extra annual cost of larger terminal = $\frac{\$125,000}{\$0.10}$ = 1,250 M-B/Y =

3,400 Bbls./Day

SOURCE: Shell Oil Company
Transportation and Supplies

Table 7

U. S. PORTS
DRAFT AND SIZE (DWT) OF TANKERS HANDLED
PRESENT AND PROPOSED

	PRESENT		PROPOSED	
PORT	MAXIMUM DRAFT TO AT LEAST ONE BERTH	LARGEST TANKER (DWT)	MAXIMUM DRAFT AFTER EXISTING PROJECT COMPLETED	LARGEST TANKER (DWT) AFTER EXISTING PROJECT COMPLETED
Portland, Me.	39'	50,000	45' - 1968	85,000
Boston, Mass.	35'	36,000	38' - 1968	47,000
New York, N. Y.	38'	47,000	45' - 1967	85,000
Philadelphia, Pa.	39'	50,000	-	-
Baltimore, Md.	37'	42,000	40' - 1969	53,000
Norfolk, Va.	37'	42,000	-	-
Mobile, Ala.	36'	38,000	38' - 1965	47,000
Houston, Tex.	34'6"	34,000	38' - 1968	47,000
Los Angeles, Cal. (Incl. Long Beach)	46'	100,000	-	-
San Francisco, Cal.	36'	38,000	45' - 1965	85,000
Portland, Ore.	33'	26,000	38' - 1970	47,000

SOURCES: Annual Report Chief of Engineers
U.S. Seaports - Port Series, Corps of Engineers, 1963
American Merchant Marine Institute
Asiatic Petroleum Corporation

Table 8
Page 1

CONSTRUCTION OF LOCKS AND DAMS ON THE OHIO RIVER

OLD STRUCTURE			NEW STRUCTURE UNDER EXISTING PROJECT			
LOCK NAME (NO.)	SIZE (FT.)	OPEN TO NAVIGATION	LOCK NAME	NO. OF LOCKS	SIZE (FT.)	OPEN TO NAVIGATION
7, 8, 9	600 x 110 (All)	1914, 1911, 1914	New Cumberland	2	1,200 x 110 600 x 110	1961
27, 28, 29, 30	600 x 110	1922, 1915, 1916, 1923	Greenup	2	1,200 x 110 600 x 110	1962
35, 36, 37, 38, 39	600 x 110	1919, 1925, 1911, 1924, 1921	Markland	2	1,200 x 110 600 x 110	1963
41	600 x 110 360 x 56	1921	McAlpine	3	1,200 x 110 600 x 110 360 x 56	1963
31, 32, 33 34	600 x 110	1919, 1926, 1921, 1925	Capt. Anthony Meldahl	2	1,200 x 110 600 x 110	1964
10, 11	600 x 110	1915, 1911	Pike Island	2	1,200 x 110 600 x 110	1965
17, 18, 19, 20	600 x 110	1918, 1910, 1916, 1917	Belleville	2	1,200 x 110 600 x 110	1967
43, 44, 45	600 x 110	1921, 1925, 1927	Cannelton	2	1,200 x 110 600 x 110	1968
12, 13, 14	600 x 110	1916, 1911, 1917	Hannibal	2	1,200 x 110 600 x 110	Authorized - Construction not started
21, 22, 23	600 x 110	1919, 1918, 1921	Racine	2	1,200 x 110 600 x 110	Authorized - Construction not started
48, 49	600 x 110	1922, 1928	Uniontown	2	1,200 x 110	Authorized - Construction not started

CONSTRUCTION OF LOCKS AND DAMS ON THE OHIO RIVER
(CONT'D.)

OLD STRUCTURE			NEW STRUCTURE UNDER EXISTING PROJECT			
LOCK NAME (NO.)	SIZE (FT.)	OPEN TO NAVIGATION	LOCK NAME	NO. OF LOCKS	SIZE (FT.)	OPEN TO NAVIGATION
15, 16	600 x 110	1916, 1917	Willow Island	2	1,200 x 110 600 x 110	Under Study
46, 47	600 x 110	1928, 1928	Newburgh	2	1,200 x 110 600 x 110	Under Study
52, 53	600 x 110	1928, 1929	Mound City	2	1,200 x 110 600 x 110	Under Study
50, 51	600 x 110	1928, 1929	Dog Island	2	1,200 x 110 600 x 110	Tentatively Proposed

SOURCES: Annual Report - Chief of Engineers, U. S. Army - Civil Works Activities - 1960
Ohio River - General Plan for Replacement and Modernization of Existing Navigation Structures - U. S. Army Engineer Division, Cincinnati, Ohio - October 1961

Table 9

FEDERAL APPROPRIATIONS FOR NAVIGATION IMPROVEMENTS
TOTAL U. S.

	$ (MILLIONS)
1963	224
1962	204
1961	211
1960	209
1959	190
1958	141
1957	135
1956	88
1955	42
1954	25
1953	31
1952	47
1951	48
1950	60
	1,655

SOURCE: 1963 Annual Report - Chief of Engineers, U. S. Army - Civil Works Activities - Vol. I

Table 10

TODAY'S FREIGHT COSTS
USING TYPICAL EQUIPMENT
(¢/BBL.)

STATUTE MILES	TANKER 25,000 DWT*		BARGE 60,000 BBL. TOW*		PIPELINES		TANK CAR 10,000 GAL.		FOR-HIRE TRUCK 8,500 GAL.	
	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
100	7.0	9.0	6.0	7.5	5.0	15.0	36.0	58.0	41.5	66.5
500	11.5	14.5	14.0	17.5	16.0	50.0	82.5	178.5	158.0	342.5
1,000	16.0	19.5	24.0	29.5	25.0	70.0	112.5	353.0	219.0	688.0
2,000	28.5	35.0	47.5	58.0			214.0	673.0		

Equivalent average mills per ton mile for 500 mile stage:

500	2.0	2.5	4.0	20.0	35.0

*Gasoline basis; includes reasonable return on investment.

SOURCE: Shell Oil Company, Transportation and Supplies, supplemented by other data from ship owners; published tariffs of selected major crude and products pipelines; representative for-hire truck and tank car rates.

BIBLIOGRAPHY

American Mercant Marine Institute	Appropriations for River and Harbor Improvement Projects		1964
American Petroleum Institute	Annual Statistical Bulletin, U. S. Petroleum Industry Statistics 1940-63		1964, pp. 13, 14
American Petroleum Institute	Petroleum Facts and Figures		1963, p. 92 (using Interstate Commerce Commission and Bureau of Mines as sources)
American Petroleum Institute	Proceedings American Petroleum Institute Section V Transportation		1963
Association of Oil Pipe Lines	Unpublished material		
Corps of Engineers, U. S. Army	Annual Report - Chief of Engineers - Civil Works Activities, Vols. 1 and 2	U. S. Gov't. Printing Office	1960 and 1963
Corps of Engineers, U. S. Army	Transportation Lines on the Mississippi River System, Transportation Series 4	U. S. Gov't. Printing Office	1963
Corps of Engineers, U. S. Army	Transportation Lines on the Great Lakes System, 1964, Transportation Series 3	U. S. Gov't. Printing Office	1964
National Petroleum Council	Oil and Gas Transportation Facilities		1962, p. 28
National Petroleum News	Fact Book Mid-May 1964	McGraw Hill	
Oil and Gas Journal	Various issues and articles		
Petroleum Transportation Handbook	Edited by Harold Sill Bell	McGraw Hill	1963
Sun Oil Co., Economics Department	Analysis of World Tank Ship Fleet December 31, 1963		Table 1

U. S. Army - Engineer Div., Cincinnati, O.	Ohio River - General Plan for Replacement and Modernization of Existing Navigation Structures	U. S. Gov't. Printing Office	1961
U. S. Bureau of Mines	U. S. and Puerto Rico Oil Imports by quarters for 1963	U. S. Gov't. Printing Office	
U. S. Dept. of Commerce	United States Foreign Trade	U. S. Gov't. Printing Office	Feb. 18, 1964
U. S. Dept. of Commerce	Merchant Marine Data Sheet, Nov. 1, 1964	U. S. Gov't. Printing Office	
U. S. Dept. of Commerce Maritime Administration	United States Seaports Port Series - Part I	U. S. Gov't. Printing Office	1963